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(54) **Circuit for starting and ballasting arc discharge lamps**

(57) A filament 21 connected in series with the arc lamp 24 provides illumination during arc start-up and functions as a ballast during normal arc operation. An oscillatory starting circuit includes a transformer (37, 38, 71) and a frequency-controlling ringing circuit (46, 38) and applies starting voltage to the arc lamp until an operating are is established. The circuit includes capacitor 43 for isolating the starting transformer from the operating path of the arc lamp, and further includes a voltage-doubling starting circuit (27, 43) and also a "keep-alive" feature 81 which prevents the arc from extinguishing during power fluctuations.

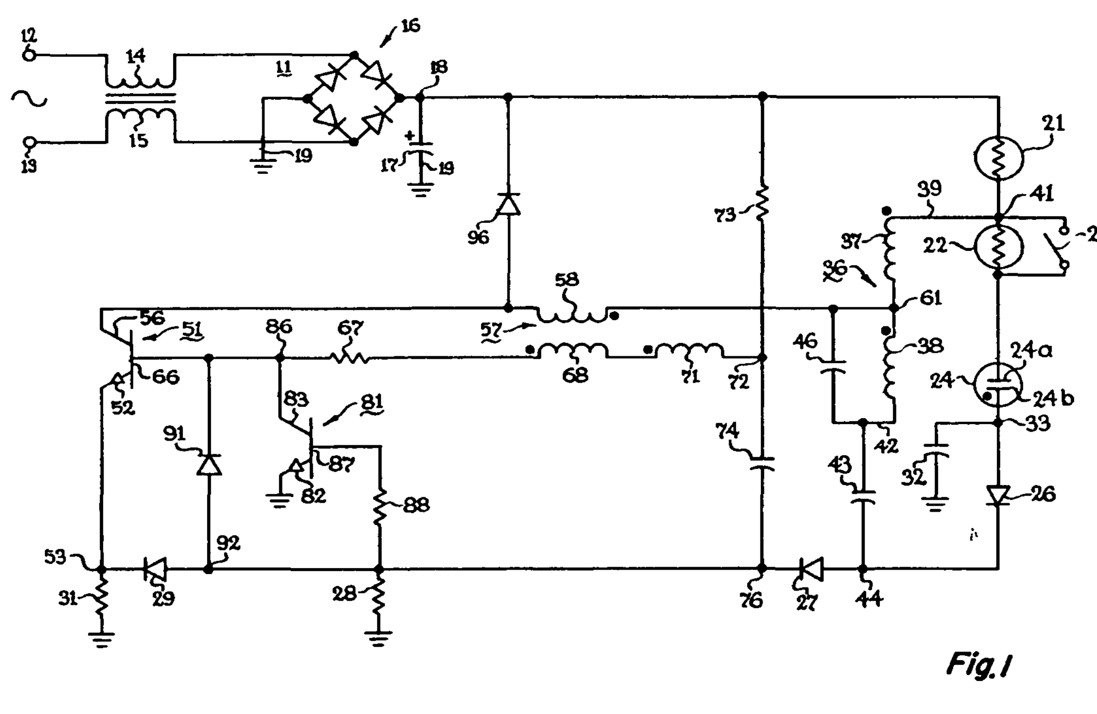

Fig. 1

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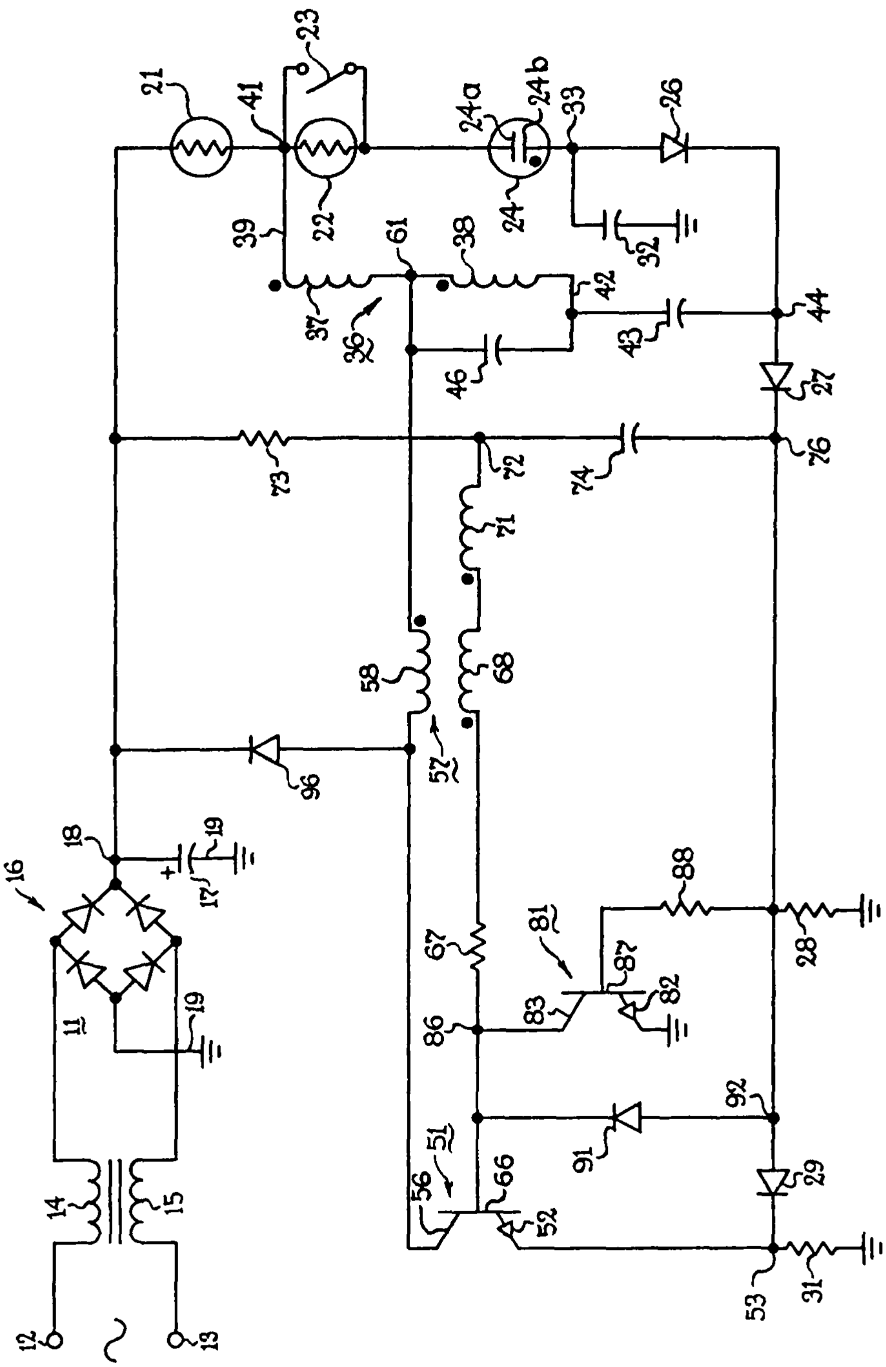


Fig.1

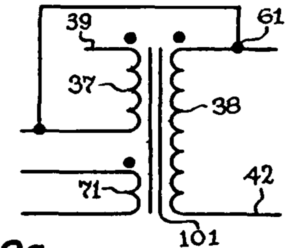


Fig. 2a

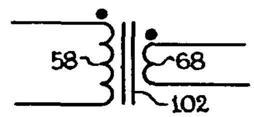
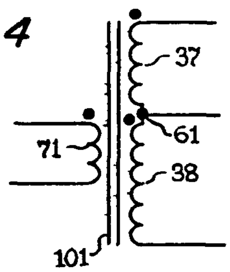


Fig. 2b

Fig. 4



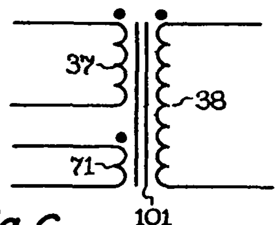


Fig. 6

Fig. 7

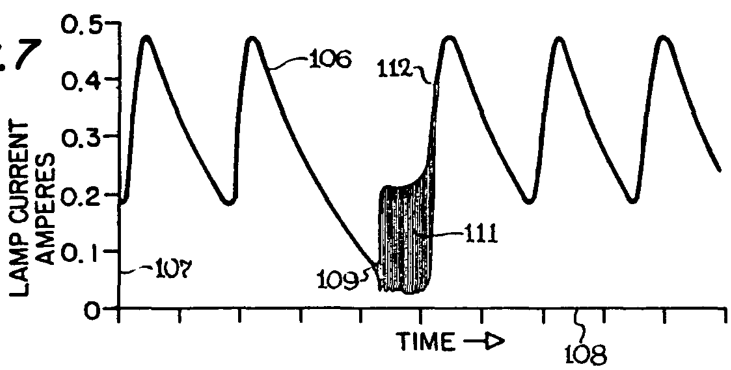
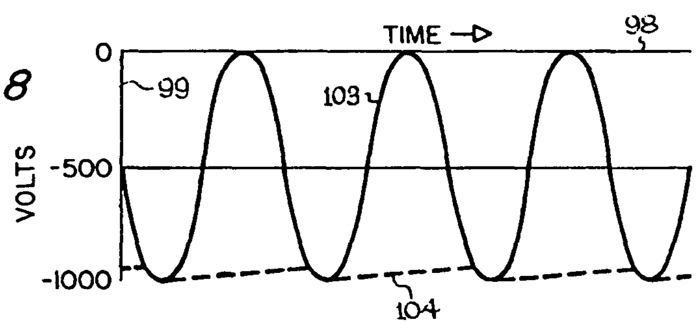


Fig. 8



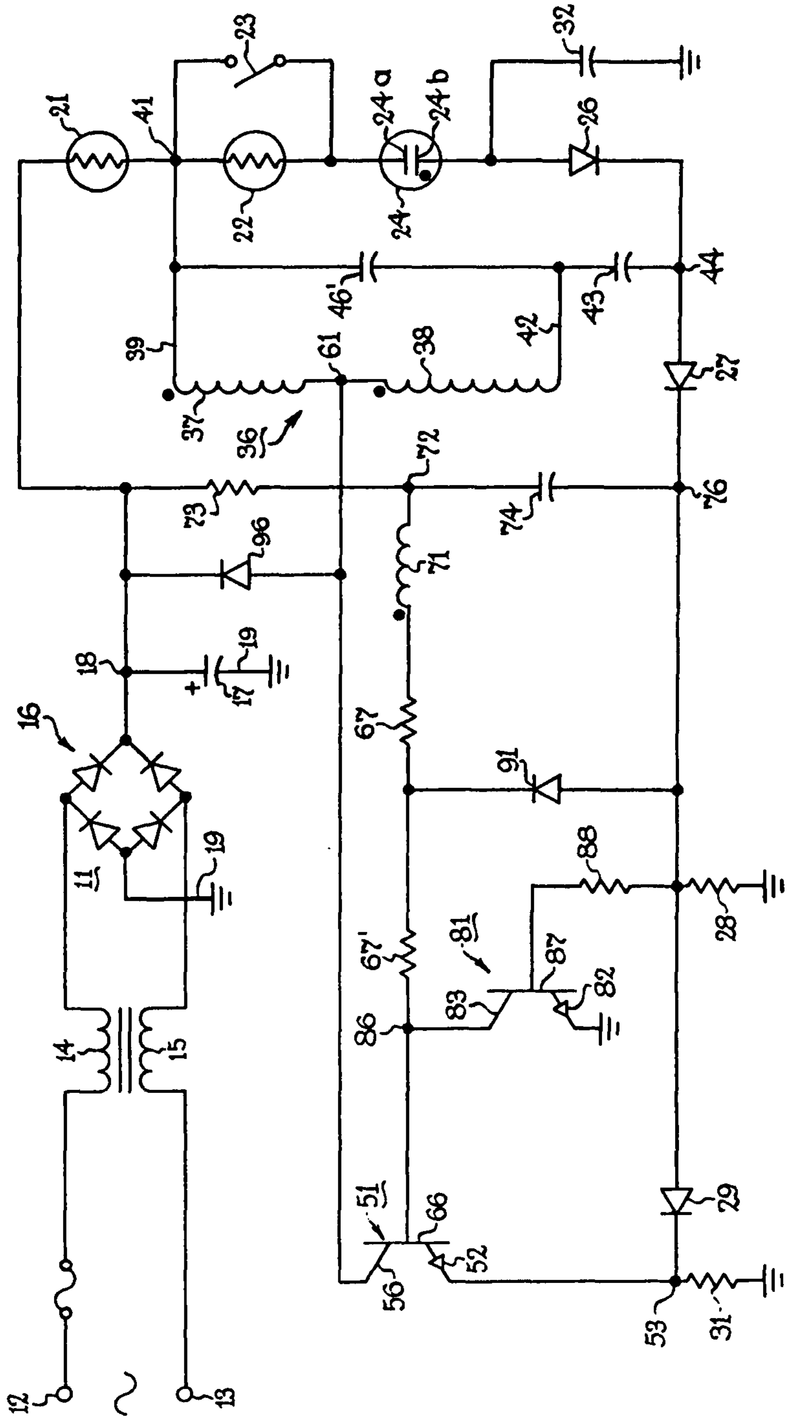

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Fig. 3

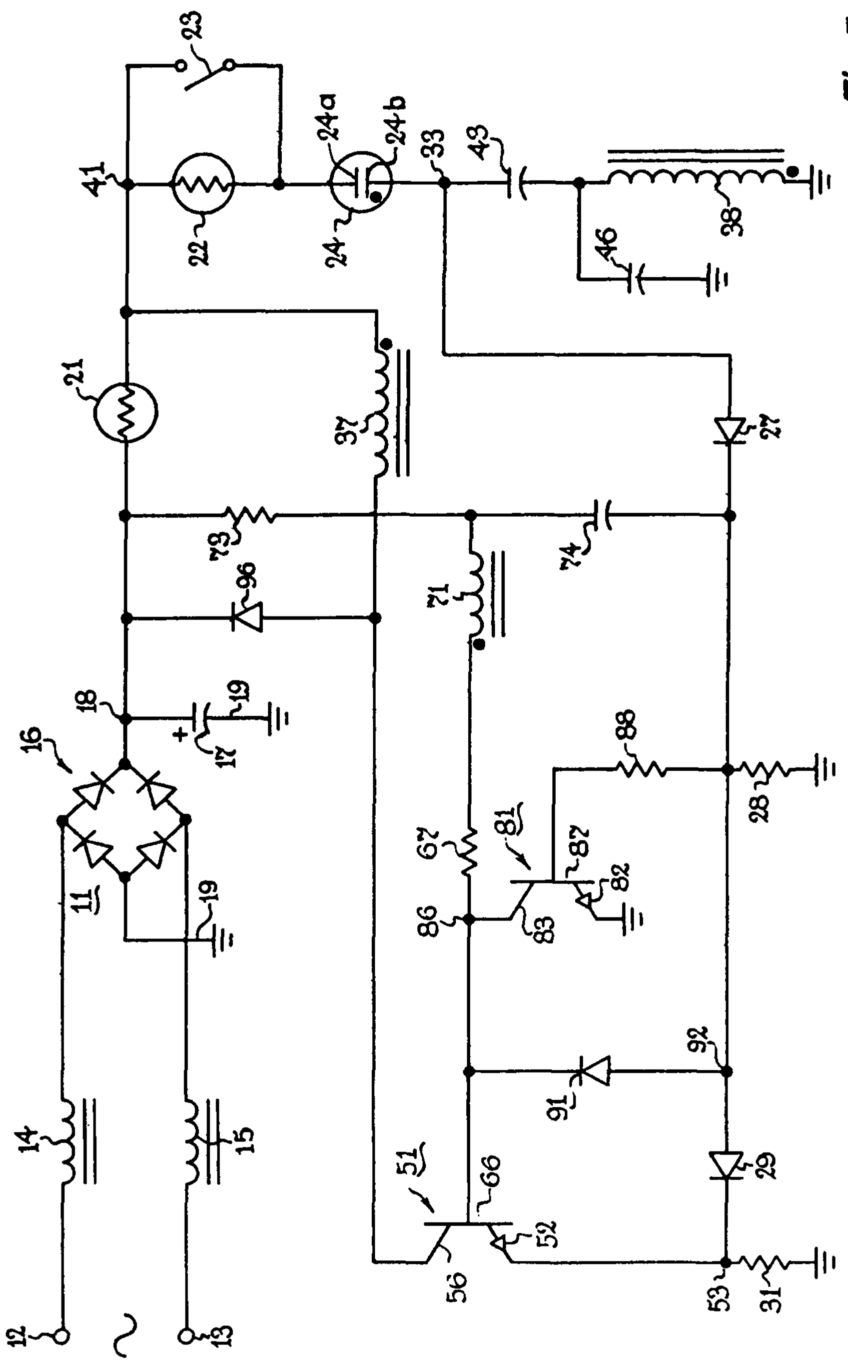
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Fig.5

SPECIFICATION

Circuit for starting and ballasting arc discharge lamps

The invention is in the field of electronic circuits for starting and ballasting and operating high-pressure, high-intensity arc lamps in contrast to low-pressure lamps such as fluorescent lamps. Low pressure lamps can be started with a single short duration relatively low voltage pulse. Low pressure lamps also do not have a hot restart problem.

This invention is directed to circuits for starting high-pressure, high-intensity arc discharge lamps, and to provide such circuits which generate increased starting voltage for a lamp in an efficient manner. The invention is also directed to provide such circuits which can be compact and included in a base of a lamp.

The invention comprises, briefly and in a preferred embodiment, a circuit for starting and ballasting an arc discharge lamp, the circuit comprising an oscillatory starting circuit including a starting transformer for generating a starting voltage for the lamp and a separate ballast means in series with the lamp for controlling the lamps' current in its operating mode.

The ballast preferably is an incandesible filament and the starting ciruit causes the filament to incandesce during the arc lamp starting mode. A capacitor is connected in series with the output winding of the starting transformer to isolate this output winding from the operating current path of the arc tube. The capacitor has a value of capacitance with respect to the frequency of the starting voltage so as to be conductive thereof. In a preferred circuit, the aforesaid capacitor also functions as part of a starting voltage doubler circuit.

The invention will be best understood when the following description is read together with the drawings in which:

Figure 1 is an electrical schematic diagram of a preferred embodiment of the invention.

Figures 2a and 2b show the winding arrangements of the two transformers in Fig. 1.

Figure 3 is an electrical schematic diagram of an alternative preferred embodiment of the invention.

Figure 4 shows the winding arrangement of the transformer in Fig. 3.

Figure 5 is an electrical schematic diagram of further preferred embodiment of the invention.

Figure 6 shows the winding arrangement of the transformer of Fig. 5.

Figure 7 shows a typical keep-alive hysteresis operation of the circuits of the schematics of Figs. 1, 2 and 5.

Figure 8 shows starting voltage waveshapes.

In Fig. 1, a d-c power supply 11 comprises power input terminals 12, 13, adapted to receive d-c voltage or typical household a-c power of 120 volts, for example, which are connect via conventional transient and/or radio-interference prevention means such as inductors 14, 15 (to isolate the circuit from line transients and/or to prevent radio-interference frequencies from passing back to the terminals 12, 13), to a conventional bridge rectifier diode arrangement 16 which produces d-c voltage charge on a filter capacitor 17 with plus polarity at its terminal 18 and minus polarity at its electrical ground terminal 19, this d-c voltage across the capacitor 17 being about 100 to 200 volts when the input a-c voltage at input terminals 12, 13, is 120 volts. The circuit will also function if a suitable d-c voltage is applied to the input terminals 12, 13.

Across the filter capacitor 17 there are connected in series, in the order named, from the + terminal 18 to the − terminal 19, an incandesible type filament 21, another incandesible type filament 22 having a manually operated shorting switch 23 thereacross, an arc discharge lamp 24, a diode 26 connected in conductive polarity, a diode 27 connected in conductive polarity, and a current sensing device such as a resistor 28. From the junction of diode 27 and resistor 28, a diode is connected in conductive polarity in series with a resistor 31, which is connected to electrical ground. A capacitor 32 is connected between the junction 33 of the arc tube 24 and diode 26, and electrical ground. In the just-described circuit, preferably the filaments 21 and 22 and the arc lamp 24 are enclosed in a single lamp bulb. The filament 21 functions to provide light during the starting mode of the arc lamp 24, and the resistor 28 functions to cause turn-off of the starting circuit when the lamp 24, reaches arc condition, and also, in accordance with the invention, functions in the "keep-alive" circuit for the arc lamp as will be described. The filament 22 and switch 23 provide two alternative illumination levels of the arc lamp 24.

An oscillatory arc-starting inverter circuit includes a transformer 36 comprising a primary winding 37 and a secondary winding 38 connected in electrical series, the free end 39 of the primary 37 being connected to the junction 41 of the filaments 21 and 22, and the free end 42 of the secondary 38 being connected via a capacitor 43 to the junction 44 of the diodes 26 and 27. A ringing capacitor 46 is connected in parallel across the secondary winding 38 to provide a "ringing" circuit therewith, as will be described.

The oscillatory starter circuit also includes a transistor 51 having an emitter electrode 52 connected to the junction of 53 of the diode 29 and resistor 31, a collector electrode 56 connected via an auxiliary transformer 57

primary winding 58 to the junction 61 of the transformer 36 primary 37 and secondary 38 windings, and a base electrode 66 is connected via a resistor 67, a secondary winding 68 of the auxiliary transformer 57, and a third or auxiliary winding 71 of the starting transformer 36, to the junction 72 of a resistor 73 and a capacitor 74 which are connected in series between the positive voltage terminal 18 and the junction 76 of the diode 27 and resistor 28.

The capacitor 43 and diode 27 constitute a starting voltage doubler circuit, and the diode 26 and capacitor 32 constitute a starting voltage peak rectifier circuit, as will be described following completion of the description of the oscillatory inverter circuit. A control circuit for the starting circuit comprises a transistor 81 having an emitter electrode 83 connected to the junction 86 of the resistor 67 and base electrode 66 of the inverter transistor 51, and a base electrode 87 connected via resistor 88 to the junction 76 of the diode 27, capacitor 74, and resistor 28, etc.

A diode 91 is connected between the base electrode 66 of inverter transistor 51 and the junction 92 of diode 27 and diode 29, oriented to be current-conductive toward the base electrode 66. Another diode 96 is connected between the collector electrode 56 of inverter transistor 51 and the + terminal 18 of the power supply.

In Fig. 2a, the windings 37, 38, and 71 of transformer 36 are shown with their relative relationships on a core 101 which may be of ferrite material. In Fig. 2b, the windings 58 and 68 of the auxiliary transformer 57 are shown with their relative relationships on a core 102 which may be of ferrite material.

The circuit of Fig. 1 functions as follows: In initial "cold condition" starting of the arc lamp 24, d-c current from terminal 28 flows through resistor 73 and charges capacitor 74, thus applying increasing positive d-c voltage and current, via transformer winding 71, auxiliary transformer winding 68, and resistor 67, to the base 66 of lamp starting inverter transistor 51, and thus "turning on" the transistor 51 and causing current to begin to flow via filament 21, starting transformer winding 37, and auxiliary transformer winding 58, to collector electrode 56 and through emitter electrode 52 to ground via resistor 31.

The increasing current through winding 58 inductively increases, via winding 68, the positive drive to base 66, for a short time as determined by the time constant of inductors 58 37, and the resistance of filament 21, to provide regenerative positive feedback for transistor 51. This increasing conduction of transistor 51 provides energy to the ringing circuit (winding 38 and capacitor 46) via inductive coupling from winding 71, causing sinusoidal voltages to occur across the windings 37, 38, and 71 at a frequency determined by the resonance frequency of the ringing circuits. The first half-cycle of this sinusoidal voltage across winding 71 has positive polarity such as to provide positive base current to the transistor 51, thus temporarily maintaining the transistor in its fully conductive condition and causing the filament 21 to emit light. The just-mentioned positive base current to transistor 51 drains charge from the capacitor 74, whereby the voltage thereacross decreases. As the sinusoidal voltage across winding 71 swings toward and through zero voltage and reverses polarity (negative polarity at the end of winding 71 toward the base 66) the sum of the voltages across winding 71 and capacitor 74 decreases and reverses, thus stopping the flow of current to base 66 and biasing the transistor 51 to become non-conductive. This turning off of the transistor 51 causes a well-known inductive voltage "kick" to be produced across the windings 58 and 37 when the current flow stops therethrough. To prevent this voltage "kick" from damaging the transistor 51, the diode 96 is provided and it conducts the energy of the inductive voltage "kick" to the filter capacitor 17, thus improving the circuit efficiency. The filament 21 is not energized while the transistor 51 is non-conductive.

The capacitor 74 becomes recharged from voltage and current energy induced in windings 71 and 68 when the current flow therethrough to base 66 ceases as described above. This recharging path includes the resistor 67 and diode 91. As the sinusoidal voltage across winding 71 next swings toward and through zero in positive-going polarity (at the end of winding 71 toward the base 66), the combined series voltage across this winding and the capacitor 74 renders the transistor 51 conductive again, and the above-described oscillatory function continues repetitively. In simple terms, the transistor 51 "pumps" the ringing circuit during each short turn-on time period of positive half-cycles of its oscillation. The "on" and "off" time periods of the transistor 51 do not necessarily coincide with the positive and negative half cycles of voltage in the windings of transformer 36, because the transistor 51 duty cycle is affected by the varying voltage on capacitor 74 and may further be affected by magnetic saturation of the transformers 36 and 57. The collector-emitter current waveshape of transistor 51 resembles a square wave, and the voltage and current waveshapes in windings 37, 38 and 71 resemble a sine or cosine waveshape. The oscillation is sustained primarily by the ringing circuit which is energised by current via the filament 21. The transistor 51 functions as a switch having main electrodes 52, 56 and a control electrode 66.

As has been explained, the oscillations in

transformer 36 are controlled in frequency by the L-C ringing circuit of winding 38 and capacitor 46 (about 20 KHz to 50 KHz, for example). The ringing capacitor 46 may be connected across any of the three windings 37, 38, 71 of the starting transformer 36, or may be connected across the series-connected windings 37 and 38, as shown in Fig. 3, provided it has a value of capacitance to resonate properly with the winding inductance. The pulsating or a-c voltage across primary windings 37 is stepped up by the secondary winding 38 and applied to a d-c voltage doubling circuit comprising diode 27 and capacitor 43.

The capacitor 43 and diode 27 are provided and connected to function as a starting votage doubler circuit, as follows. Insofar as the voltage doubling function is concerned, the upper end 39 of primary winding 37 is in effect connected to electrical ground via filament 21 and filter capacitor 17, and the cathode of diode 27 is connected to electrical ground via resistor 28 and also via diode 29 and resistor 31. Thus the capacitor 43 and diode 27 are in effect connected in series with the across an output winding comprising the combined primary and secondary windings 37 and 38. Assuming that the peak-to-peak combined value of alternating voltage in the windings 37 and 38 to be 500 volts, whenever this voltage has positive polarity at the end of windings, the diode 27 becomes conductive and the capacitor 43 becomes charged to 500 volts with positive polarity at point 42 and negative polarity at point 44. Then, during the alternate half-cycles when the 500 volts across windings 37 and 38 is negative polarity at point 42 and positive polarity at point 39, the total summation voltage across windings 37, 38 and the capacitor 43 is 1,000 volts, i.e., the transformer voltage becomes doubled at point 44, with respect to electrical ground. This doubled voltage at point 44 is rectified by diode 26 and filtered somewhat by capacitor 32, and a starting voltage comprising this doubled d-c voltage (of negative polarity) produced across capacitor 32, and a starting voltage comprising this doubled d-c voltage (of negative polarity) produced cross capacitor 32, added to the positive polarity d-c voltage at electrode 24a (100 volts, for example), is applied across the electrodes 24a and 24b of the arc lamp 24, for a short time period until the gas in the lamp 24 becomes "broken down" or ionized into a "glow" state. This increased starting voltage initiates the glow state more quickly and reliably.

In Fig. 8, which has a horizontal time axis 98 and a vertical voltage axis 99, curve 103 is representative of the doubled starting alternating voltage at point 44 of the circuit, and reaches a peak value of 1,000 volts negative, for example. The dashed-line curve 104 in Fig. 8 is representative of the d-c glow-actuating voltage at point 33 of the circuit. After the arc tube 24 breakdown into flow mode, it enters into a flow-to-arc transition (GAT) mode for several seconds until an operating arc is established during which transition the glow current in the arc tube is high enough so that the filter capacitor 32 is relative ineffective and essentially an a-c voltage is applied across the arc tube in the GAT mode. In an alternative embodiment, the rectifier 26 and filter capacitor 32 can be omitted and the a-c voltage at point 44 is applied to arc tube 24 for initiating the glow discharge; however, this loses the above-described advantage of the additional 150 volts or so positive polarity starting voltage at electrode 24a of the arc tube. During the starting mode time interval, the filament 21 provides initial lamp illumination.

During the aforesaid starting mode of the arc lamp 24 the current through the lamp 24 and series resistor 28 is sufficiently low so that the voltage drop across resistor 28 biases the control transistor 81 in the "off" condition, i.e., with none or low current through its emitter 82 – collector 83 path. When the aforesaid operating arc discharge is established in the arc tube 24, the current in the series resistor 28 reaches a sufficient value to establish a high enough voltage across resistor 28 to switch the control transistor 81 into the "on" condition so that it draws current, through its collector-emitter path and through resistor 67 and transformer windings 68 and 71 and resistor 73, to render the bias on transistor 51 base electrode 66 sufficiently relatively low to turn the starting transistor 51 "off", thus stopping the starting voltage generation and permitting the arc tube 24 to draw current from the power supply 11 and operate in normal mode as biased by the filament 21 (which now generates low or none incandescent illumination). The operating dimming switch 23 can be manually or otherwise opened or closed if desired to cause reduced or increased illumination of arc tube 24 due to the added or reduced series resistance ballast.

The capacitor 43 is provided in series with the transformer windings 37 and 38 to electrically isolate these winding from the d-c operating current path of the arc lamp 24 and thus prevent current of the power supply 11 from flowing through these windings, which current flow would be wasteful of energy and would require the use of larger-diameter wire for these windings, which in turn would cause the transformer to be larger and heavier and to have more heat loss. Further, the capacitor 43 is connected in series with the secondary winding 38 so as to additionally function to couple the starting voltage out of the transformer 36, and still further to function with the diode 27 to provide a voltage doublint circuit

as has been described. When the arc lamp 24 operates from d-c current, as has been described, the capacitor 43 can have a value of capacitance sufficiently large to perform its functions of coupling the starting voltage from the transformer 36 and of operating in a voltage doubler circuit; there is no upper limit on the value of capacitance. In accordance with another feature of the invention, the arc lamp 24 can be operated from an a-c power source having a frequency considerably lower than that of the a-c starting voltage. For example, the a-c starting voltage has a frequency of about 20 KHz to 50 KHz as described above, the a-c operating frequency for the arc lamp 24 can be about one KHz or lower, and the value of the capacitor 43 is chosen sufficiently low so as to adequately block the a-c lamp operating frequency, while at the same time having a sufficiently high capacitance value to adequately pass the higher frequency of the a-c starting voltage and to function in the voltage doubling circuit.

When the arc tube 24 is in normal d-c operating mode, its d-c current flows from power supply terminal 18 through ballast resistor 21 (and in series through additional dimming ballast resistor 22 if the dimming switch 23 is opened), through the arc lamp 24, diodes 26 and 27, and the path to ground of resistor 28 and the series connected diode 29 and resistor 31 which are in parallel with resistor 28. The diode 29 and resistor 31 function to limit the maximum voltage drop across resistor 28, for example, to 1.4 volts. the capacitor 43 prevents the arc tube operating current from flowing through the transformer windings 37 and 38.

Fig. 7 illustrates the arc tube operating current waveshape 106, on a current axis 107 with respect to a time axis 108, which is the normal operating waveshape except for a center portion which will be described. The normal operating arc current is not pure d-c, and fluctuates periodically with the rectification of rectifier 16, because the capacitance value of the main filter capacitor 17 is chosen as low as feasible for achieving reliable operation of the arc lamp 24. A larger value of filter capacitor 17 would provide a smoother arc current 106, but would be more costly and of larger physical size. Having a value of 50 microfarads in a preferred embodiment, the capacitor 17 is one of the larger components of the circuit, along with the transformers 36 and 57.

One type of typical arc tube 24, for example, has a voltate drop of about 85 volts thereacross, during normal arc operation, at an average arc current of about 350 milliamperes.

In the event that the normal illuminating arc current in the arc tube 24 should begin to falter or fail, such as due to a temporary reduction or interruption of d-c power from the power supply 16, which may be due to a temporary fluctuation in input a-c power supply at input terminals 12 and 13, the arc "keep alive" feature of the circuit functions as follows. A reduction in normal arc current 106 in the tube 24, such as to a "dangerously low" value at 109 in Fig. 7 (70 millamperes, for example), causes a reduction of current in the series resistor 28 to a value at which the voltage across resistor turns the control transistor 81 "off", thus turning the starting transistor 51 "on" (the reverse of the aforesaid turning on and off of these transistors when the operating arc becomes established in arc tube 24), whereupon the aforesaid starting circuit begins to generate starting voltage for the arc lamp 24, before the arc in the lamp 24 has time to extinguish, thus maintaining the arc before it completely extinguishes, and restoring it to normal operating mode. This "keep alive" starting voltage is the same as shown in Fig. 8, and its typical current waveform is indicated at 111 in Fig. 7, and it persists until the arc lamp current resumes a normal operating value such as the point 112 in Fig. 7 (350 millamperes, for example), whereupon the voltage across control resistor 28 causes the starting circuit to turn off as has been described. This "keep-alive" feature thus prevents the arc in lamp 24 from accidentally extinguishing completely which would involve the undesirable "hot restart" mode in which the arc lamp must be allowed to cool for a time period, such as a minute or so, before it can be restarted. The "keep-alive" starting voltage circuit is less sensitive to power supply voltage fluctuations than is the arc tube 24, and thus can operate from a power fluctuation to a low voltage value that would cause the arc in tube 24 to extinguish.

The "keep-alive" circuit feature is designed to have a hysterisis effect by which the starting circuit is actuated when the arc current falls to a relatively low given value such as 109 iun Fig. 7 and continues oscillating until the arc current builds up to a relatively higher desired operating given value such as at 112 in Fig. 7 and continues oscillating until the arc current builds up to a relatively higher desired operating given value such as at 112 in Fig. 7. This hysteresis effect is achieved in two cooperating ways simultaneously, as follows.

While the oscillatory starting circuit (comprising transistor 51 and transformers 37 and 57 and capacitor 46) is functioning, the positive half cycles of oscillatory energy in the winding 71 provide current into the base 66 of transistor 51, via winding 68 and resistor 67, the return path of this positive current being via resistors 31, 28, and capacitor 74. This current through resistor 28 is in the opposite direction as in the current flowing therethrough from the arc lamp 24, thus

causing a lower voltage drop across resistor 28 than would be caused by the current from the arc lamp 24. Thus the arc current in lamp 24 must be build up to a higher value (at or near point 112 in Fig. 7) in order to increase the voltage on resistor 28 to a value to bias transistor 81 on and transistor 51 off, to stop the starting voltage oscillations, than the value of arc current at point 109 in Fig. 7 which caused the starting oscillator to function.

The second way in which the aforesaid hysteresis effect is achieved involves the gain of transistor 81. When the starting circuit is not operating and the transistor 81 is conductive, a low value of current flows into the collector 83, as determined by the value of resistors 67 and 73 and the supply voltage at 18, and therefore the base current into base 87, via resistors 28 and 88, is a low value. However, when the starting voltage circuit is operating, in order for the control transistor 81 to become conductive and turn off the oscillating voltage, it must divert a relatively large current, via its collector 83, from the base 66 of transistor 51. This requires a higher value of base current into base 87, and hence a higher value of arc lamp current through resistor 28, to render the transistor 81 conductive and cause the starting circuit to stop oscillating than was required to cause the control transistor 81 to turn off and cause the oscillator to turn on when the arc lamp current reached a "dangerously low" value at point 109 in Fig. 7. This contributes to the aforesaid hysteresis effect the arc current builds up to a normal operating value such as at the point 112 in Fig. 7.

The circuit embodiment of Fig. 3 is generally similar to that of Fig. 1, and the same components are designated by the same numerals. The Fig. 3 circuit omits the feedback transformer 57 shown in Fig. 1, and its function is performed by the transformer 36 which is constructed so that the primary winding 37 is magnetically more tightly coupled to the auxiliary winding 71 than it is to the secondary winding 38. Thus the windings 37 and 71 additionally function as a feedback transformer whereby increasing current through winding 37 to collector 56 causes increased current to the base 66 via the inductive coupling of windings 37 and 71, which in turn causes increased collector current, etc. In Fig. 3 the ringing capacitor 46' is connected across the series-connected primary and secondary windings 37 and 38, and has a value so as to resonate with these windings at a desired starting voltage frequency. A resistor 67' is added in Fig. 3, between resistor 67 and the base 66 of transistor 51, and it functions to increase the "on" time periods of the oscillating transistor 51 and thus increase the average current through the filament 21 thereby increasing its brightness. This is accomplished by providing more resistance in the discharge path of capacitor 74 into the base of 66 of transistor 51 than the value of resistance in the recharging path of capacitor 74. More specifically, the resistive discharge path of capacitor 74 includes resistors 67, 67', 31, and 28, whereas the resistive path for the recharge of capacitor 74 by the aforesaid inductive kick in winding 71 includes only the resistor 67 (because of diode 91). Thus the capacitor 74 discharges relatively more slowly and the transistor 51 is "on" longer than its "off" periods during which the capacitor 74 recharges relatively more rapidly. This asymetrical wave shape of transitor 51 is "on" longer than its "off" periods during which the capacitor 74 recharges relatively more rapidly. This asymetrical wave shape of transistor 51 does not affect the sinusoidal waveshapes in windings 37, 38, and 71 since the transistor 51 relates to these windings only during its short-duration turn-on times during which the changing current in winding 37 induces current in windings 38 and 71 and "pumps" the ringing circuit. During the steady-state "on" periods of transistor 51, the filament 21 is energized and the only waveshape changes in windings 37, 38, and 71 is caused by the ringing circuit.

The circuit embodiment of Fig. 5 is generally the same as Fig. 1, but omits the feedback transformer 57 in the manner described above for Fig. 3, and has the secondary winding 38 connected so as not to be in electrical series with nor directly connected to primary winding 37. Also in Fig. 5, the starting voltage rectifier diode 26 and filter capacitor 32 of Fig. 1 have been omitted, and the arc tube is started with a-c voltage.

Some typical component values in a preferred circuit are as follows:

Capacitor 17:	50 microfarads
Capacitor 32:	50 picofarads
Capacitor 43:	0.003 microfarads
Capacitor 46:	0.003 microfarads
Capacitor 74:	0.1 microfarads
Resistor 28:	10 ohms
Resistor 31:	1.5 ohms
Resistor 67:	47 ohms
Resistor 73:	39K ohms
Resistor 88:	1 K ohms
Filament 21:	60 watts
Filament 22:	40 watts

The above-described circuits have been tested and found to function well in starting, running, and maintaining ("keep-alive" feature) arc lamps, in the manner described. Also, the circuit generates relatively little heat, largely due to the feature of the starting transformer being isolated from the operating current path of the arc tube, and thus the circuit can be compact and included in a base portion of the lamp, with the arc tube 24 and

filaments 21 and 22 being in a bulb portion of the lamp. The base portion can include a threaded part so that the unitary lamp unit can be screwed into electrical sockets. As described above, the increased value of starting voltage initiates the initial glow in the arc tube quickly and reliably, and in a manner more economical and more feasible than would be achieved by doubling the number of turns in the secondary winding 38. Expressed another way, the voltage doubling circuit permits a reduction in the number of turns required for the secondary winding 38. An advantage of fewer secondary turns is that the secondary can provide greater current to the arc tube during the flow-to-arc transition time period.

The current sensing resistor 28, referred to generally herein as a current sensing device, could be replaced with other suitable components such as a bilaterally conductive semiconductor device or a plurality of semiconductor devices arranged to provide a bilaterally conductive system, e.g. a pair of diodes connected in parallel with unlike electrodes connected together.

CLAIMS

1. A circuit for starting and operating a gas-filled, high-pressure high-intensity type of arc lamp from an electric power source, characterized by an oscillatory starting circuit including a transformer having an output winding for providing pulsating voltage of given frequency, means for applying to said arc lamp a starting voltage derived from said output winding for a time period until an operating arc is established in said lamp, means to inactivate said oscillatory circuit when said operating arc is established, means connected for ballasting said arc lamp for operation from said electric power source, and a capacitor in series with said output winding for isolating the output winding from the operating current path of said arc lamp, said capacitor having a value of capacitance sufficiently large with respect to said frequency of the pulsating voltage to as to be conductive thereof.

2. A circuit as claimed in Claim 1, characterized in that the ballasting means comprises an incandescible filament connected in electrical series with said arc lamp, said starting circuit including means for causing said filament to incandesce and provide light during said time period until an operating arc is established in the arc lamp.

3. A circuit as claimed in Claim 2, characterized by an envelope enclosing said filament and said arc tube.

4. A circuit as claimed in any one of Claims 1 to 3 characterized by a diode connected to said capacitor to form therewith a voltage doubler circuit for said pulsating voltage, whereby said capacitor functions as a component in the voltage doubler circuit in addition to its said function of isolating the output winding from the operating current path of the arc lamp.

5. A circuit as claimed in Claim 4, characterized by a rectifier connected to peak-rectify the doubled voltage produced by said voltage doubler circuit, and a filter capacitor connected to the output of said rectifier, to provide a d-c voltage for causing initial ionization of the gas in said arc lamp.

6. A circuit as claimed in any one of Claims 1 to 5 characterized by a current sensing device connected in series with said operating current path of the arc lamp, and in which said oscillatory starting circuit includes a switch device having a control electrode, and control means connected between said current sensing device and said control electrode for biasing said switch device in the "off" condition and hence turning off said oscillatory starting circuit in response to a desired value of arc lamp operating current being reached.

7. A circuit as claimed in Claim 6, characterized in that the current sensing device is a resistor.

8. A circuit as claimed in Claims 6 or 7 characterized in that the current sensing device and control means function to bias said switch device to the "on" condition and activate said oscillatory starting circuit whenever the operating arc lamp current dips to a "dangerously low" value, and means for feeding some current of the oscillatory circuit through said current sensing device in a direction opposite to that of said arc lamp current whereby said control circuit turns off the oscillatory circuit when the arc lamp current rises to the desired operating value which is greater than the "dangerously low" value which activated the oscillatory starting circuit.

9. A circuit as claimed in any one of the preceding claims characterized in that the oscillatory starting circuit includes a switch device having a pair of main electrodes and a control electrode, and in which said transformer includes a primary winding and an auxiliary winding both inductively coupled to said secondary winding, said primary winding being electrically connected in series with the current path of said control electrode, and a ringing capacitor connected across one or more of said windings to form a ringing circuit with the inductance thereof for controlling the frequency of oscillation in said windings.

10. A circuit as claimed in Claim 9, characterized in that the frequency of oscillation is about 20 KHz to 50 KHz.

11. A circuit as claimed in Claims 9 or 10 characterized in that the primary and output windings are connected together in electrical series.

12. A circuit as claimed in any one of the preceding claims characterized in that the

electric power source has a frequency sufficiently lower than that of said pulsating voltage to be substantially blocked by said capacitor.

13. A circuit as claimed in Claim 12, characterized in that the electric power source is a d-c source.

14. A circuit as claimed in Claim 12, characterized in that the pulsating voltage has a frequency of about 20 KHz to 50 KHz and said electric power source has a frequency of about one KHz or lower.

15. A circuit for starting and ballasting arc discharge lamps substantially as described herein with reference to Figs. 1, 2a and 2b, Figs. 3 and 4, or Figs. 5 and 6 of the accompanying drawings.

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